EFFECTS OF BONDING PARAMETERS OF BASALAT FRP BARS ON THE BEHAVIOR OF RC COLUMNS

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1. INTRODUCTION

In recent seismic design philosophies, quick post-earthquake recoverability of structural function of bridges located in active seismic regions has been considered secondary to the ductility demand (Kawashima et al. (1998)). Moreover, the post-yield stiffness ratio (i.e., the ratio of the post-yield stiffness to the initial elastic stiffness) of a bridge column has been considered as the main parameter controlling column residual displacement (Wu et al. (2009). Furthermore, Wu et al. (2009) emphasized that the uncontrollable damage of conventional steel-reinforced concrete (RC) structures is due to the elasto-plastic characteristics of ordinary steel bars. Fiber reinforced polymer (FRP) bars has an elastic characteristics and a poor ductility with excellent durability. Therefore, by reinforcing RC bridge columns with a combination of steel and FRP bars, the post-yield stiffness is improved and the residual displacement is mitigated. The bond performance between FRP bars and the surrounding concrete may directly influence the stress transfer and the structural behavior of such columns. Therefore, understanding the effect of bonding behavior of FRP bars on the performance of concrete columns is an essential step before accepting the concept of steel-FRP RC (FSRC) columns. In this study, nonlinear finite element (FE) as well as experimental bond-based analysis is performed on basalt FRP (BFRP)-steel RC columns to get insight into the effects of BFRP bars-concrete bonding parameters on the performance of RC columns.

2. BONDING BEHAVIOR OF BFRP BARS

Aiming to evaluate the effect of surface texture on the bond-slip characteristics of BFRP bars, pull-out tests on 10-mm-diameter BFRP bars with two different surface texture configurations (Fig. 1.a) were carried out. Where one bar surface (BF-S) was characterized by small indentations (factory product) and the other (BF-R) was created by adding cross spiral roughening to the factory produced bar. The bond-slip curves for both the two BFRP bars are shown in Fig. 1.b. In addition to that, a bond-slip curve of 10-mm-diameter ribbed steel bar (S-R) is superimposed in the same figure for comparison. It is evident from Fig. 1.b that BF-S and BF-R bars shared the same initial bond stiffness with the steel bar up to approximately 60% and 90% of the maximum bond strength, respectively. Beyond that, the stiffness of BFRP bars became smaller than that of steel bars up to the maximum bond strength, at which a plateau was created followed by the descending branch up to reaching the residual bond strength. It is also clearly appeared that by roughening the bar, the bond strength significantly increased (i.e., the bond strength of BF-R was approximately the same as that of S-R) and the slope of the descending branch slightly increased. Based on the results of this test, two models for the bond-slip behavior of BFRP bars (model 1 and model 2) were developed for the BF-S and BF-R bars, respectively, as superimposed on Fig. 1.b. Consequently, a general bond-slip model for BFRP bars was proposed, as shown in Fig. 1.c.

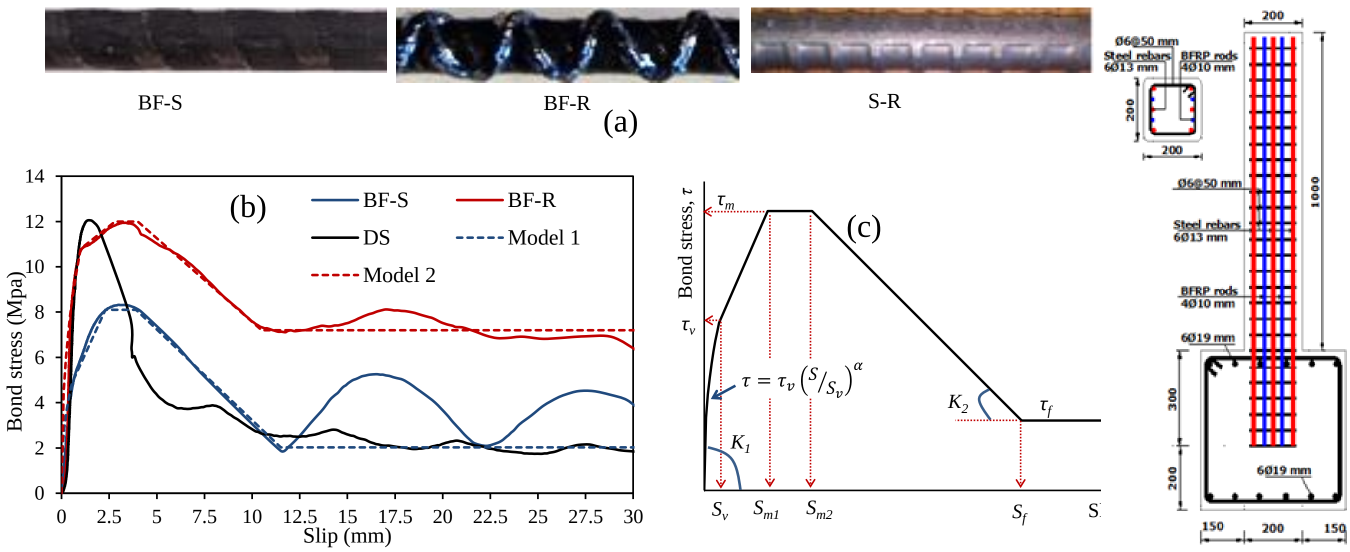

Fig. 1 (a) Surface texture configurations of BFRP and steel bars, (b) Bond-slip relationships resulted from pull-out tests, (c) Proposed bond-slip model for BFRP bars, and (d) Dimensions and reinforcement details of the FSRC column

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3. NUMERICAL PARAMETRIC STUDY AND EXPERIMENTAL VERIFICATION

A very detailed 3D-FE model using ANSYS code version 13, with cracking and nonlinearity capabilities, was performed to investigate the effect of bond characteristics between the BFRP bars and the surrounding concrete on the behavior of the FSRC column, shown in Fig. 1.d. To simulate the bond behavior between steel bars and concrete, the well-known local bond stress-slip relationship proposed by Model Code 90 (CEB (1992)) for good bond conditions was employed. On the other hand, the proposed bond-slip model for FRP bars, Fig. 1.c, was used to simulate the bonding behavior of the BFRP bars. It is very clear from Fig. 2 that by altering the bond-slip parameters, specially the peak bond strength and its corresponding slips and the slope of the descending branch, the post-yield stiffness ratio, the stability at the peak strength, the loading degradation, and the failure mode are significantly affected. In order to verify the numerical findings, two FSRC columns (CSF-S and CSF-R) were tested under the effect of constant axial load and reversed cycling loading. The two columns were reinforced with four 10-mm-diameter BFRP bars having surface types of BF-S and BF-R, respectively in addition to six 13-mm-diameter steel bars, Fig. 1.d. The results of the experimental tests agreed well with the numerical findings, as shown in Fig. 3.

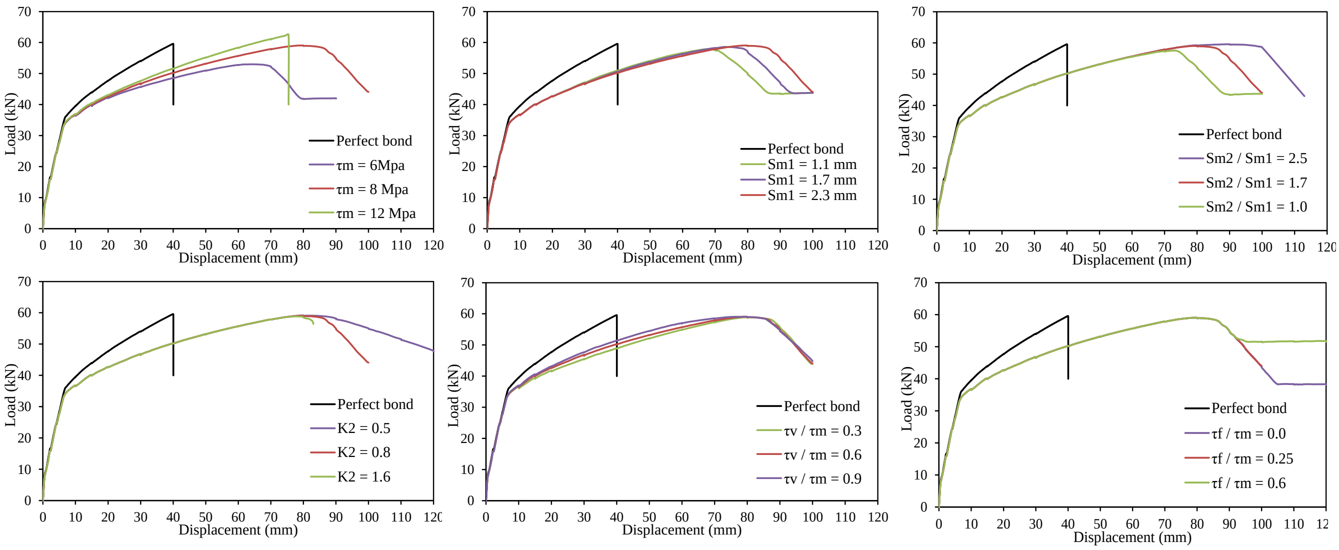

Fig. 2 Effect of bonding parameters of BFRP bars on the load-displacement relation of FSRC column

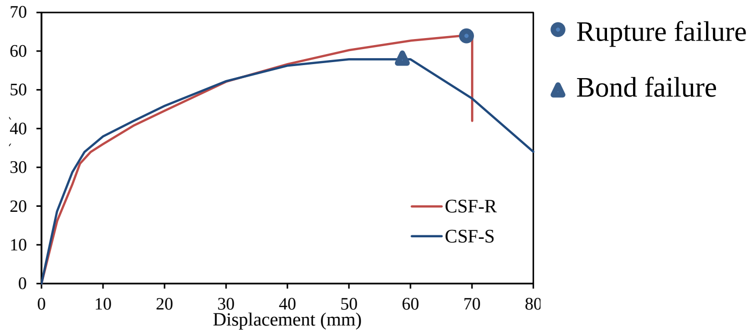

Fig. 3 Experimental load-displacement relations of columns reinforced by BFRP bars with surface texture BF-S (column CSF-S) and surface texture BF-R (column CSF-R)

4. CONCLUSIONS

The results of this study revealed that all numerically examined bond conditions including perfect bond conditions did not show any clear effect on column elastic stiffness; but, post-yield stiffness, stability zone, and ultimate ductility were very sensitive to bond conditions between FRP bars and concrete. Experimental results showed a good agreement with the numerical findings where different bond conditions showed different post-yield stiffness, ductility, and failure modes.

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